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Adaptation to flood and salinity environments in the Vietnamese Mekong Delta: Empirical analysis of farmer-led innovations

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ABSTRACT

Agriculture is exposed to climatic impacts, especially in developing countries. Adaptation is the predominant practice that farming communities undertake to deal with these climate-induced challenges. While significant attention has been devoted to farmers' adaptation strategies, little is known about how innovative practices are associated with the improvement of rural livelihoods. To address this gap, the paper attempts to investigate how farmers lead the process of rural innovations that constitute successful forms of adaptation to address the mixed impacts of dyke policies and climate change in two distinct agro-ecological zones (i.e. flooding and salinity) in the Vietnamese Mekong Delta (VMD). Drawing on qualitative information collected from focus group discussions and interviews across the case studies, the paper argues that farmers are the key innovation actors who contribute to improving rural farming and water management practices. The study suggests that the evolution of farmer-led innovations is mainly attributed to the operation of various informal learning networks that provide important platforms for the generation and diffusion of effective innovative practices across farming communities. It also highlights how farmers contribute their innovative knowledge to local adaptation policies. From the policy perspective, this study sees the development of rural innovation systems as the best practices of farmers' adaptation, which needs to be scaled out to better support agricultural water management in the delta.

1. Introduction

Agriculture is the backbone of economies in most developing countries, which are exposed to climatic impacts. In Asia, floods, droughts, and sea level rise are prevalent phenomena that adversely affect agriculture-based livelihoods (Dewan, 2015; Karim and Rahman, 2015; Smajgl et al., 2015). Addressing these 'wicked' problems presents critical needs for developing innovative adaptation practices and mainstreaming them into development policies (Halsnæs and Trærup, 2009; Mertz et al., 2009). At the local level, common innovative adaptation patterns include changes in crop management practices, livelihood strategies, and agricultural water management strategies (Bryan et al., 2013; Iglesias and Garrote, 2015). These approaches are important assets that complement communities' efforts towards poverty reduction and enhancement of rural livelihood conditions (Pouliotte et al., 2009; Tambo and Wunscher, 2017).

An innovation is "an idea, practice, or object that is perceived as new" (Rogers, 2003: 12). Innovations include not only the adoption of a new agricultural technology, but also a wide range of other processes or the application of a new learning and teaching method (Spielman et al., 2011). They are the products of collaborative learning networks, whereby experimental and experiential knowledge is produced and disseminated across geographical boundaries (Knickel et al., 2009; Beers et al., 2010; Kilelu et al., 2013). In the agricultural context, innovations are the driving force for the achievement of food security and rural poverty reduction (Leitgeb et al., 2011; Brooks and Loevinsohn, 2011).

Farmers have played a pivotal role in agricultural innovations (Chambers et al., 1993; Beckford et al., 2007; Leitgeb et al., 2011; Tambo and Wunscher, 2017). Goulet (2013) perceive farmers as not merely the receivers of innovations, but rather the producers and holders of knowledge. According to Klerkx and Leeuwis (2008: 366), farmers are seen as agricultural entrepreneurs "who play an important position in acquisition of knowledge and information to support their

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business strategies and innovation projects." They also form various informal learning networks (e.g., farmer field school, farm visits) to assist joint learning and knowledge exchange (Oreszczyn et al., 2010; Kilelu et al., 2013; Dolinska and d'Aquino, 2016; Tran et al., 2018). Living close to nature enables farmers to continually create innovative approaches to cope with environmental impacts (Swiderska, 2014). In responding to climate change, farmers in Nepal interact with institutional systems to design technological innovations (Chhetri et al., 2012). Demonstrated in other forms, farmers in Kenya and Ghana engage in formal and informal agricultural knowledge systems whereby they can learn and disseminate innovations (Adolwa et al., 2017). In northern provinces of Vietnam, farmers interact with local extension workers to collectively build and implement agricultural models (Friederichsen et al., 2013).

Innovations take place through the process of adaptation (Rodima-Taylor et al., 2012; Daouda and Bryant, 2016). In developing countries, innovations are driven by collective efforts of rural communities in modernizing agricultural production and tackling pressures from rural development policies, change in rural landscapes, and adverse impacts of climate change (Spielman et al., 2011; Chhetri et al., 2012; Friederichsen et al., 2013; Adenle et al., 2015; Adolwa et al., 2017). In the face of these constraints, farmers secure their livelihoods through innovative practices (Osbahr et al., 2008; Motsholapheko et al., 2011; Bosma et al., 2012; Tang et al., 2013; Martin and Lorenzen, 2016). While this scholarship is largely recognized in developing countries of Africa and Asia (Chhetri et al., 2012; Singh et al., 2015; Tambo and Wunscher, 2017), the relative importance associated with farmers' innovations in farming and water management is poorly acknowledged in the Vietnamese Mekong Delta.

This study attempts to provide an exploratory analysis of how rural innovations constitute successful forms of adaptation in addressing adverse impacts of dyke policies and climate change in the flooding and salinity environments of the VMD. We define rural innovations as innovative adaptation strategies whereby farmers undertake to respond to environmental constraints. By exploring the evolution of rural innovations in the case study areas, the study contributes to gaining better insight into the role farmers play in local farming and water management practices. It also highlights collaborative learning between famers and extension officials and their efforts in translating innovative practices into rural adaptation policies.

2. Background

The majority of inhabitants in the VMD depends on agricultural and aquacultural production as essential means of livelihoods (Cosslett and Cosslett, 2014). The total natural area of the delta amounts to 3.9 million hectares (ha), of which about 65% of the land (2.6 million ha) is devoted to agriculture (Ha et al., 2018). The region contributes more than 70% of rice and 50% of aquacultural products to the total foreign export (Chu et al., 2014a,b). These activities are sustained by the rich availability of freshwater resources supplied by the overflows from the Mekong River, high tidal levels from the sea, and local heavy rainfalls, starting from July through to December (Le et al., 2007a). High floods cover 8 provinces with 10 million people, of whom nearly 75% living in rural areas are affected (Vo, 2012). The delta climate is influenced by two distinct seasons: the dry season from December to April and the wet season from May to November (Nguyen et al., 2012).

The delta is characterized by three major agro-ecological zones, including the high flooded, low flooded freshwater and the saline intrusion zones (Chu et al., 2014a,b). In these zones, about 1 million ha are affected by tidal flooding and 1.7 million ha (about 45% of the delta area) by saline intrusion (Le et al., 2007a). The last few decades have seen the extensive development of water control projects to enable intensive agricultural production in the delta. In the upstream areas, floods are controlled by the density of dyke systems and sluice gates to enable rice production and other cash crop systems (Nguyen et al., 2012, 2013). Similarly, between 1994 and 2000 witnessed the building of series of sluice gates along the coast of the Ca Mau Peninsula to control salinization and support rice-based agriculture systems (To et al., 2003). The development of large-scale water control schemes has driven the uneven distribution of floods upstream (Le et al., 2007b; Delgado et al., 2012; Dang et al., 2016), while aggravating adverse effects of saline intrusion in coastal zones (To et al., 2003; Nguyen and Van, 2014). Additionally, the dyke systems have transformed the physical landscapes (Tran and James, 2017) and degraded the ecological systems in the delta (Chapman et al., 2016; Tong, 2017). Driven by climate change and hydrological fluctuations, the upper delta has experienced frequent flood variations in the wet season (Kuenzer et al., 2013; Dang et al., 2016), while aggravating saline intrusion in coastal areas in the dry season (Albers and Schmitt, 2015; Renaud et al., 2015; Smajgl et al., 2015). These dual effects have constrained the delta-wide socio-economic development, directly affecting water-based livelihoods at the local level (Vo, 2012). In this study, we focus on the high flooding and the salinity zones where the local livelihood activities are profoundly exposed to environmental change (Käkönen, 2008). It is interesting that, apart from perceived impacts, the environmental change in these zones has stimulated farmers to learn and develop a wide range of innovative practices.

3. Research methods

3.1. Case study areas

In this study, we selected the study areas in the high flooding and salinity zones of the VMD (Fig. 1). In the floodplains, three communes, namely Phu Thanh B (Tam Nong district, Dong Thap province), Phu Xuan (Phu Tan district, An Giang province), and Thoi Hung (Co Do district, Can Tho city) were selected. These flooding areas include the Plain of Reeds, the upper floodplain, and the tide-affected floodplain (Tanaka, 1995). They are typically characterized by the density of flood control and irrigation schemes aiming at supporting intensive agricultural production. The flood protection embankments (e.g., low and high dykes) allow the cultivation of multiple rice crops (e.g., double or triple rice cropping) (Chapman et al., 2016; Tong, 2017) and integrated farming systems (Le et al., 2006; Bosma et al., 2012). In the coastal zone, Long Phu and Dai Ngai communes of Long Phu district (Soc Trang province) were selected. Affected by saline intrusion, local farmers adopt aquacultural activities (e.g., shrimp farming) as the main livelihoods (Käkönen, 2008; Ha et al., 2013; Renaud et al., 2015). However, in dyke-protected areas of the coastal zones, rice-based agricultural systems remain dominant (Renaud et al., 2015). It is important that the diversity of livelihoods in these two agro-ecological areas means that local farmers have learned to adapt to the local environments. It also suggests how the development of innovative practices characterizes an important aspect of adaptation in the delta.

3.2. Methods for data collection and analysis

This study employed the exploratory multiple case study research design (Yin, 2012). This approach has been applied to explore the innovation potential of smallholder farmers in the Caribbean countries (Lowitt et al., 2015). In this study, we used qualitative data gathered from focus group discussions (FGDs) and in-depth interviews to examine how rural innovations have emerged and developed in the flooding and salinity zones of the delta (Table 1). The main topics under study concern how farmers got involved in learning practices and how these processes led to the emergence of the innovations that benefit farmers' livelihoods. The exploration of how farmer-based informal learning networks are associated with the evolution of the innovations provides important insights into how farmers contribute to rural development. Due to the poor knowledge of how rural innovations are derived from farmers' adaptation practices in the VMD, the application of the exploratory approach in this study is critically important.

Household participants recruited for FGDs in this study was based on the participatory approach. In particular, we coordinated with local

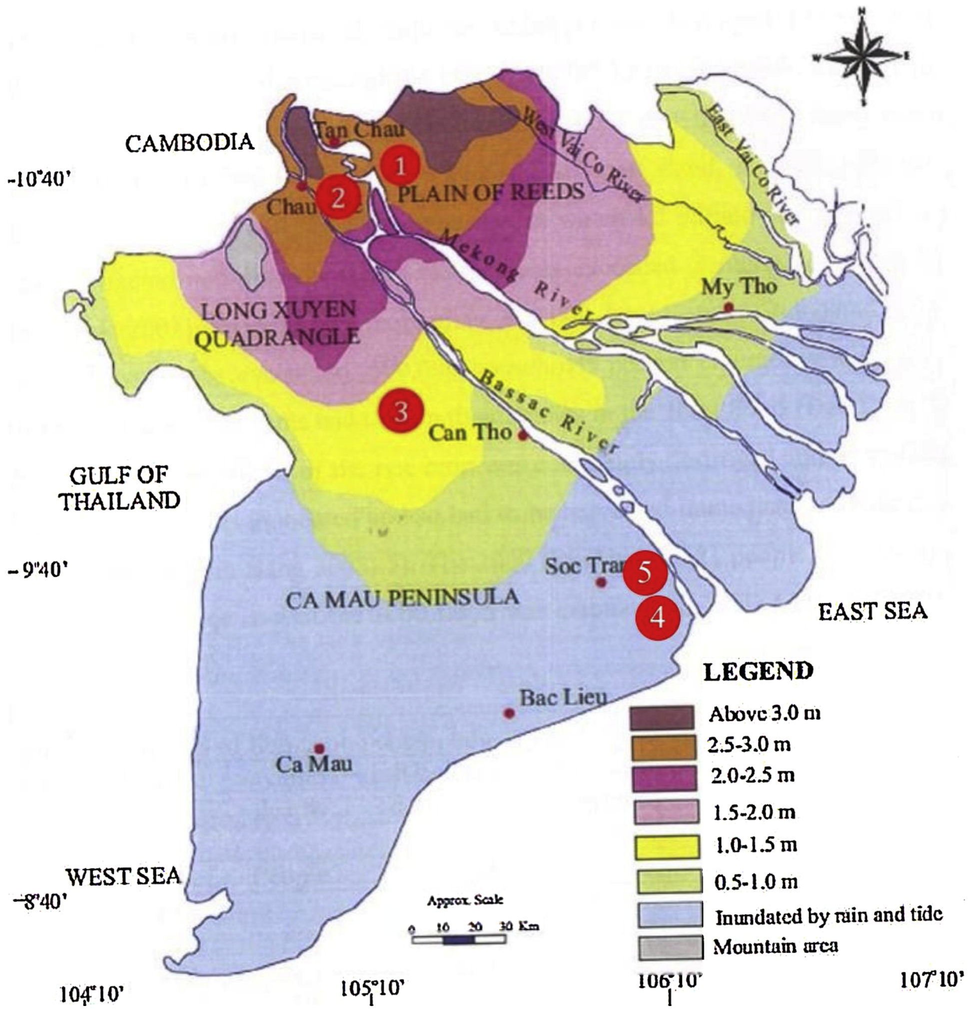

Fig. 1. The VMD map and the selected study areas: (1) Phu Thanh B (Dong Thap province), (2) Phu Xuan (An Giang province), (3) Thoi Hung (Can Tho city), (4) Long Phu, and (4) Dai Ngai (Soc Trang province). Source of based map: Ghassemi and Brennan (2000).

government officials and farmer representatives to determine a set of criteria (e.g., socio-economic characteristics, occupation) from which household samples for FGDs were built. Those who are engaged in farming activities (e.g., rice farmers, fish farmers …) were recruited because they are directly affected by the local environments. In total, nine FGDs in the flooding and six FGDs in the saline intrusion zones were respectively undertaken. Key questions concern the impacts of floods and saline intrusion on their livelihoods, corresponding adaptation options, and learning practices to address these environmental conditions.

This study involved the application of purposive sampling and snowball sampling methods to approach key informants (Liamputtong, 2013). Key informants included local government officials (communal, district, provincial), environmental scientists, agricultural extension officials, and senior farmers who have in-depth understanding of flood and saline intrusion situations, farmers' livelihood conditions and their adaptation performance to environmental conditions. Overall, thirty-three interviews with key informants in the flooding and twenty-four in the saline intrusion zones were undertaken respectively.

The data analysis strategy involved the application of thematic analysis assisted by NVivo software (Bazeley, 2007), which assists the identification of themes emerged from the data. Following Neumanös (2011) approach, the analysis was inductively implemented. The exploratory technique eventually identified several key themes, including farmers' role in learning practices, farmers' innovation processes, and the diffusion of rural innovations across geographical scales. Besides the thematic analysis of the primary data, this study involved the content analysis of literature (e.g., policy documents, scientific reports,) relevant to rural adaptation policies and practices in the two agro-ecological areas. This complementary analysis yields important insights, contributing substantially to enriching the understanding of the issues under study.

4. Results and discussion

4.1. Dyke-driven transformation of rural landscapes

Water control and irrigation constitute the key component for agricultural development in the VMD. This was realized by the extensive construction of dykes and irrigation schemes spanning both upstream (flooding) and downstream (salinity) areas (Vo et al., 2017). Such development process has driven the substantial transformation of the physical landscapes in tandem with critical socio-environmental impacts in the delta (Tran and James, 2017). It was observed that incremental impacts of climate change (e.g., droughts) have added greater pressures to local hydrological regimes (Le et al., 2007b; Kuenzer et al., 2013). The complex interactions between flood regimes upstream and saline intrusion in coastal areas under these combined impacts have substantial implications for water-based livelihoods of the rural populations (Hoang et al., 2018).

There exists the fragmentation of water control and irrigation systems in the delta. This is attributed to various socio-economic development priorities demanded by local governments. Given the high flooding conditions and the early success in prawn cultivation, the government of Phu Thanh B finds it essential to maintain low dyke

Table 1
Summary of focus group discussions and in-depth interviews for the study.

Methods	Study sites		Participant selection and data analysis	Information gathered
	Selected communes in the flooding zone Phu Thanh B, Phu Xuan, Thoi Hung	Selected communes in the coastal zone Long Phu, Dai Ngai		
Focus group discussions (FGDs)	Nine FGDs in the three communes	Six FGDs in the two communes	Selection of participants based on the participatory approach (King and Horrocks, 2010; Neuman, 2011) Thematic analysis (Neuman, 2011) assisted by NVivo	Situations of floods and saline intrusion, impacts of floods and saline intrusion on farmers' livelihoods, corresponding adaptation strategies and learning practices in dealing with environmental changes
In-depth interviews	33 interviews with government officials, environmental scientists, agricultural extension officials, and senior farmers	24 interviews with government officials, environmental scientists, agricultural extension officials, and senior farmers	Purposive sampling and snowball sampling (Liamputtong, 2013) Thematic analysis (Neuman, 2011) assisted by NVivo	Local impacts of floods and saline intrusion on farmers' livelihoods and respective adaptation strategies Contribution of farmers' learning effects to local adaptation policy

systems to foster flood-based farming practices (e.g., wild fish capture, freshwater prawn cultivation …). This decision not only support better-off farmers but provide important means of livelihood for poor counterparts in the flood season. In the case of Phu Xuan, the year-round flood protection of the North Vam Nao scheme allows farmers to cultivate multiple rice crops (e.g., 3 years, 8 crops) and short-term cash crop systems. Scheme compartments allow the seasonal rotation of rice crops and provide rooms for flood retention in times of heavy rains or excessive flood flows upstream in the wet season. In Thoi Hung commune, the local government maximizes the benefits of using dyke systems to support integrated farming systems (e.g., rice-fish culture).

The state policy to promote rice-based agricultural production realized by the extensive building of control projects, including irrigation canals, dyke systems, and sluice gates during the 1990s (Chu et al., 2003; Käkönen, 2008) adds to environmental change in the coastal zones. The shrimp market profitability since late 1990s had enabled the dramatic shift from rice-based agricultural to aquacultural production, which triggered the significant transformation of the coastal physical landscapes (Käkönen, 2008; Ministry of Science and Technology (MST), 2016). In Soc Trang province, for instance, the anticipated profits of shrimp led to the extensive wreckage of built structural systems to direct the inflows of brackish water into rice fields (Cosslett and Cosslett, 2014; Ministry of Science and Technology (MST), 2016). These actions contribute to a radical change in land use patterns, natural resources and conficts between rice and shrimp farmers (Nguyen et al., 2010).

4.2. Farming and water management innovation practices

Developing innovative livelihood practices is closely associated with farmers' choice of farming patterns in response to the changed environmental conditions (Yohannes et al., 2017). There are various innovative forms of agriculture and aquaculture-based adaptation across the communes. Table 2 presents various innovative adaptation strategies undertaken by farmers in flooding and salinity zones. In the floodplains, farmers took advantage of structural systems (dykes) and abundant availability of floodwater to implement a variety of farming practices. For instance, farmers in Phu Thanh B shifted from snakehead fish to the freshwater giant-prawn farming practice, making creative use of the local high-flooding systems. In Phu Xuan commune, farmers raised fish in field ditches or took the commune roadside sections to plant short-term cash crops (e.g., luffa). Some others raised eels and used trash fish[1] captured in the flood season as feeds for cultured eels. The irrigation system 'one bund, two ditches' makes it possible for farmers in Thoi Hung commune to implement a variety of integrated farming systems (e.g., growing fish in rice fields) or intercrop a variety of short-term cash crops with mangoes (Fig. 2). Another study by Berg (2002) found the similar results that this farming model provides a sustainable alternative to rice monoculture from both economic and ecological perspectives. An informant in Thoi Hung described how the 'one bund, two ditches' system supports the rice-fish farming as follows:

"The ditch provides room for fish nurseries and acts as a refuge for fish when the field water level is low. As the summer-autumn rice is at the second month growth stage, young fish are released into the rice field. Before rice harvesting, water is drained to drive the fish back to the ditch. The fish return when floodwaters are flushed into the rice fields. Reproductive rice[2], organic matter, and nutrients available in the fields provide feeds for the fish." (Interview 14)

Salinity is one of the key factors that constrains the production of cereal crops, especially rice (Singh et al., 2008). Therefore, farmers in

[1] Trash fish are of low value. For this reason, they are utilized as feeds for cultured fish in the delta.

[2] After the summer-autumn rice crop is harvested, the remaining stems continue to grow and reproduce rice grains, known as reproductive rice *(lúa chét)*. In flooded fields, rice grains fall into floodwaters and provide feeds for fish.

Table 2
Innovative adaptation strategies adopted by farmers across the agro-ecological zones.

Categories	Environmental conditions	
	Flooding	Salinity
Farming practices	Growing freshwater giant prawn farming taking advantage of the high flooding system (e.g., Phu Thanh B commune) Building ponds to raise fish, using trash fish caught in the flood season as feeds for cultured fish Switching more profitable cash crops (e.g., sesame…) rather than rice Adopting multiple cropping systems (e.g., double or triple rice crops) within the dyke systems Implementing the intensive small-scale farming practice: (*Vườn* (Orchard), *Ao* (Fish pond), *Chuồng* (Poultry pen)) Practicing the integrated freshwater aquaculture (e.g., integrated rice-fish farming) Implementing agricultural diversification based on the availability of dyke systems	Reduction to single rice crops Growing salinity rice tolerant in high elevation areas Growing alternative cash crops (e.g., sugarcane …) to adapt to salinity Adjusting seasonal schedules for growing fish and rice to avoid high-level salinity Cultivating shorter-duration rice varieties Shifting from integrated rice-fish farming to integrated rice-shrimp farming practices
Water management practices	Adopting the 'one bund, two ditches' irrigation management model, using the bund to cultivate short-term crops or fruit trees and the ditches to grow fingerlings before being released to the rice fields (e.g., Thoi Hung commune) Removing sluice gates at main headworks, creating more room for free freshwater flows and replenishment of nutrients in soils (e.g., Thoi Hung commune)	Digging an internal ditch across the rice field to harvest freshwater Place canvas under small ponds to store freshwater Storing freshwater in branches of canals around the commune and controlling salinity by sluice gates

the coastal communes implemented various innovative adaptation strategies to deal with the salinity impacts. In particular, they replaced rice with sugarcane which can better withstand in salinity-affected soils. Farmers also shifted from single rice to multiple rice crop patterns. Growing rice in higher elevation areas was also one of key measures to deal with intense salinity. Results from in-depth interviews with local informants revealed that fish farmers flexibly adjusted schedules to release fish. To avoid risks of salinity to the survival of fish, farmers selected the fingerlings of larger sizes for cultivation.

Rural innovations are characterized by farmers' enterprise and creativity in generating and adopting new production approaches that benefit themselves. In the flooding areas, the successful story of a freshwater prawn farmer in Phu Thanh B commune demonstrated his sustained efforts in conducting on-farm experimentation and interactions with fellow farmers and with flooding environments. Equally important, this illustrated his opportunistic perception of floods as resources rather than constraints whereby he took advantage of. In the salinity areas, farmers saw the integrated rice-shrimp model as an alternative to the rice-fish farming in response to harsh salinity conditions. This strategy both helps increase the farm productivity and addresses the shortage of freshwater in the dry season. Similar to their counterparts in the flooding zones, farmers in the coastal communes perceived salinity as both a constraint and a natural resource benefit (Chu et al., 2003). This change in understanding enabled them to practice a variety of farming models to diversify sources of income during the dry season.

Farmers play an important role in irrigation water management in their farm plots (Mutambara et al., 2016). In Soc Trang province, to minimize the salinity impacts, farmers dug an internal ditch system across the rice field, which serves as a channel to both drain out saltwater and store freshwater. This innovative approach has proven effective to maintain soil moisture and prevent salt deposition in the farmlands. Farmers also pumped freshwater into canals or small ponds with a stretching canvas placed underneath (Fig. 3). This provides a better means to store and use freshwater for crop irrigation in conditions of prolonged hot days or freshwater scarcity. As expressed by a farmer in Soc Trang:

"Besides the rainwater stored during the rainy season, I usually keep freshwater in ponds which is covered by a plastic canvas. This helps me effectively deal with extensive salinity periods." (Interview 6)

The study identified numerous constraints faced by poor farmers during the adaptation process. Poor farmers in the flooding zones, for the most part, had limited access to resources (e.g., land, financial capital) to maintain their traditional livelihoods or shift to alternative income-generating activities. They become increasingly dependent on local landowners for employment (e.g., building field bunds, weeding, or spraying pesticides), of which the wages are often low and unstable. Evidence suggested that the mechanization of agricultural production and declining agriculture-based employment induced by dyke building constitute a driving force for the increasing migration of the poor to urban areas (Tran and James, 2017). According to Black et al. (2011), this migration allowed people to diversify income and build resilience in response to stressors, and contribute to rural poverty reduction (Huynh and Le, 2011; Scheffran et al., 2012). In the salinity zones, poor farmers implemented off-farm or self-employment activities to earn a living, including collecting scraps, petty trading, bricklaying and carpentry during saline intrusion periods. They can also benefit from labor demands (off-farm activities) from shrimp farmers (To et al., 2003). As pointed out by Ovwigho (2014), off-farm activities constitute a continuous stream of income to cater for exigencies of life, especially for the poor.

4.3. Learning as a pathway for rural innovations

The rural 'communities of practice' in the VMD provides an open space for the generation of innovations (Tran et al., 2018). Farming innovations are often achieved through farmers' collaborative learning (Wu and Zhang, 2013) and the process of knowledge exchange (Nooteboom, 2000). Our study suggests that the development of innovations was derived from learning through farmers' acquisition and consolidation of experiential and experimental knowledge represented by their communication with others. As a farmer in Phu Thanh B commune put it: "We friends treat each other very well. My friends came over and provide useful prawn farming techniques. I really appreciated that." In the same way, farmers in Thoi Hung commune articulated that maintaining regular communication with their fellow farmers and local traders enable them to adopt new farming technology and innovate crop patterns to meet emerging market demands. From the perspective of social learning, Dessie et al. (2013) claimed that innovation is not a sole effort of trying something new, but a result of successfully integrating a new idea and networking and interactive learning with multiple actors. Additionally, learning occurs through self-reflection processes. For instance, farmers in Soc Trang province used their own experience in detecting the salinity level. A FGD with local farmers suggested the experiential knowledge that "if water reflects the star light at night, it is indicative of high salinity."

Rural innovations are socially constructed. Farmers play a key role in constructing and channeling innovations within their learning networks. In this sense, the innovative knowledge is built through formal interactions with local extension officials or agricultural experts at

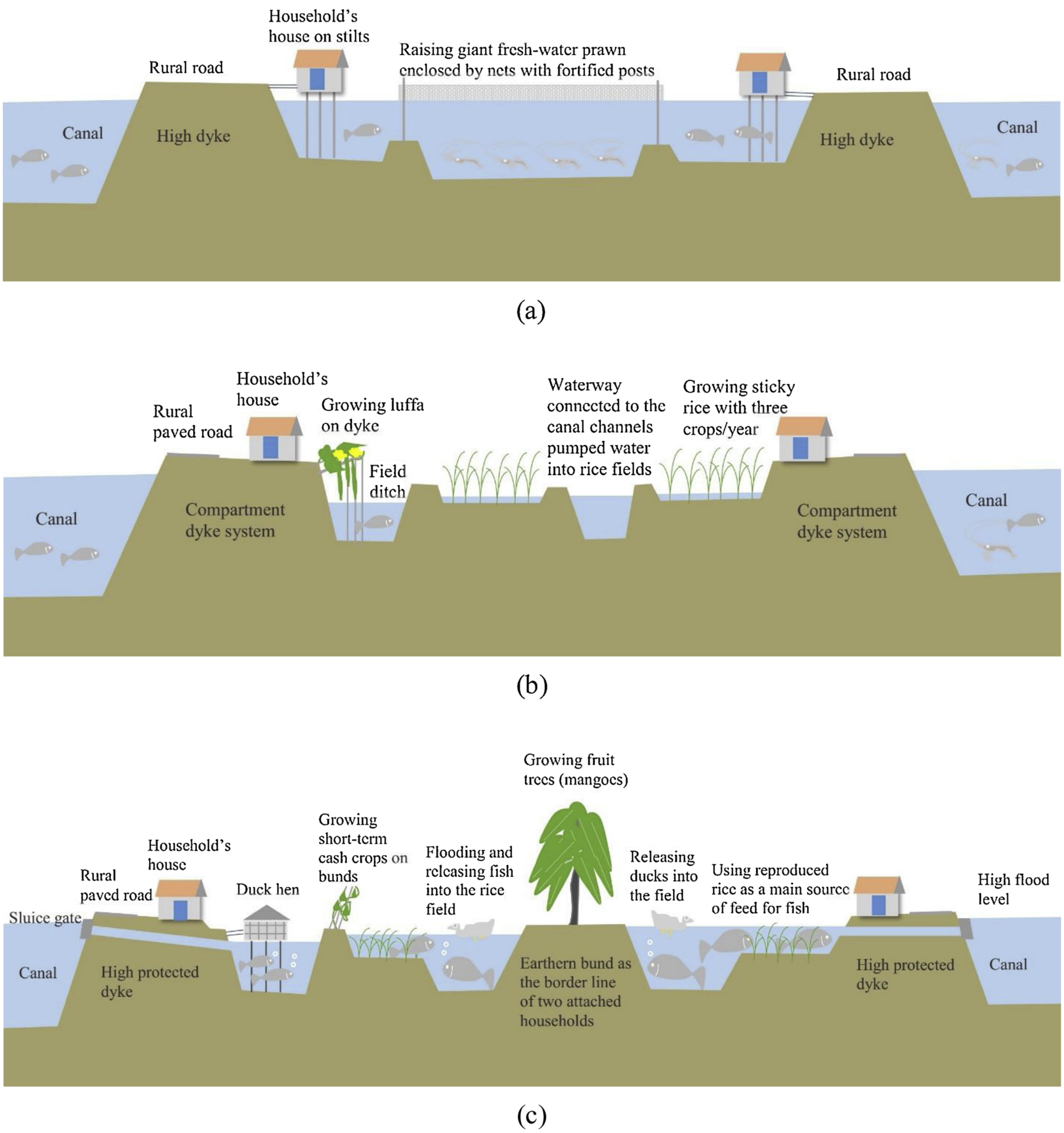

Fig. 2. Innovative adaptation practices in the flooding zones: (a) Raising the giant freshwater prawn in Phu Thanh B, (b) Growing short-term crop and fish in the ditches in Phu Xuan, and (c) Implementing the integrated rice-fish farming in Thoi Hung. Source: The first author.

Fig. 3. An innovative freshwater storage approach in Soc Trang province. Source: Ngo, 2016.

various learning platforms (e.g., seminars, training workshops) and informal communication with their bonding networks (neighbors, relatives, friends). As similarly found in the flooding and salinity areas, farmers communicate their experiences through farm visits, convivial gathering (e.g., tea, coffee or anniversaries) at home or working in the fields. These everyday activities spontaneously form informal learning networks or 'communities of practice' in which collaborative learning occurs (Tran et al., 2018). These findings were consistent with (Chambersös et al., 1993) studies on how farmers contribute their empirical knowledge in the rural context in Africa. To some extent, this challenges the domination of the science-driven conventional knowledge (Šūmane et al., 2017). From the innovation perspective, farmers are the key agents for rural change (Dolinska and döAquino, 2016). Highlighting the role of farmers in this regard, Beckford (2002) argued that farmers' views must be taken into account when accessing the usefulness of their innovations.

This study identified a strong connection between farmers and extension officials through shared learning practices. These activities promoted the exchange between local and scientific knowledge, enabling farmers to advance their local knowledge and extension officials to obtain practical understanding of farming innovations and consolidate their theoretical knowledge. The findings corroborate the Peruvian case of Potato Park on the collaborative learning between farmers and scientists in improving local innovations (Swiderska, 2014). These linkages enabled local farming communities to share the knowledge system of conserving potato varieties and simultaneously negotiate broader access and benefit-sharing agreements with scientists. In this study, the collaborative learning between farmers and extension officials on the one hand provided an empirical foundation for scientific acknowledgement and assert the validity of the farming innovations, and facilitated the translation of farming innovations into the local adaptation policies on the other hand. However, it is equally recognized that while external interventions may present constraints to local natural environment conditions, it would be necessary for decision makers to provide more room for famers to develop innovative practices to minimize negative impacts (Yohannes et al., 2017).

4.4. Contribution of farmers' innovations to local adaptation policies

Farmers' innovations make an important contribution to the reframing of local development policies. The success of the prawn farming model in Phu Thanh B entered into policy discourses, which subsequently enabled institutional learning and adjustment of adaptation practices. In Thoi Hung commune, cash crop farming practices (e.g., intercropping) gained greater recognition by the local government as an essential means to generate seasonal income for farmers. These insights correspond to Leitgeb et al.'s (2011) study that Cuban farmers contribute their experiments and innovative knowledge to the local agricultural innovation systems. Given the substantial evidence of farmers' knowledge contribution to sustainable and resilient agriculture, Šūmane et al. (2017) called for the formal and equitable recognition of farmers as co-authors of knowledge generation and practitioners in innovation processes. In the adaptation context of the VMD, the recognition of farmers' contribution to the local farming innovation systems has been gradually improved.

Contribution of farmers' innovative farming models into the local adaptation practices represents a policy learning process (Eckerberg and Joas, 2004). As Ingold and Varone (2012) denoted, this is an essential component of institutional change. From the perspective of polycentric governance, Chu et al. (2014a,b) emphasized that, despite being bound in the context of strong state power, an 'inclusive' decision-making process can occur. The iterative interactions between government officials and farmers, to some degree, shape and reshape 'the rules of the game' that meet their own needs (Chu et al., 2014a,b). These farming innovation impacts indicate the greater recognition of the value and influence of locally-based farming innovations, which not only challenges the conventional technological approach but also complements the existing policy gaps in rural development and poverty reduction. As the traditional top-down decision-making process is not adequate to provide appropriate solutions to local communities, innovations suggest local efforts in promoting the development of local knowledge to bridge such gaps (Blanco, 2006). Enhanced recognition and promotion of farmers' role in this regard provides a powerful stimulus for further development of rural innovations. Highlighting the contribution of farmers in this regard, Swiderska (2014: 53) pointed out that:

"The current top-down approach of investing heavily in scientific innovation but ignoring small-scale farmers not only misses the risks to farming communities' stock of knowledge, built up over generations, but also actively erodes farmers' ability to adapt to climate challenges."

5. Conclusions

The evolution of rural innovations led by farmers in this study represents how farmers have learned to adapt to environmental changes in the VMD. It suggests the ways farmers persistently explore and utilize their own experiences of local environments and develop innovative forms of knowledge supported by everyday communications and interactions with others. This reflects the mixed values of what Taylor (2001) terms 'a spirit of pioneering, even of adventure' held by rural farmers in response to environmental challenges.

Learning is a key component to farmers' development of farming and water management innovations. Various learning platforms (e.g., casual gatherings, in-house training) enable farmers to acquire a wide range of knowledge provided by fellow farmers and agricultural experts. These processes consequently turned farmers as learners into innovative practitioners.

The case studies in the flooding and salinity zones demonstrate the significance of collaborative learning between farmers and extension officials, contributing substantially to policy learning on the ground. The policy change in adaptation suggests meaningful bottom-up feedback that influences the reframing of the decision-making process to address the environmental issues. Greater attention to this process not only helps sustain the continuing spirit of the rural communities to foster the development of rural innovation systems, but also promote the institutionalization of innovative knowledge into rural development policy. It is equally important that the local government should formalize, facilitate, and scale up collaborative networks to accelerate rural innovations on a larger scale and benefits the wider farming communities (Wu and Zhang, 2013). From the policy perspective, this study sees the development of rural innovation systems as the best practices of farmers' adaptation. Maintaining these efforts would make significant contribution to improving the resilience of farming communities in the delta.

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